A Model-driven Sensor Web

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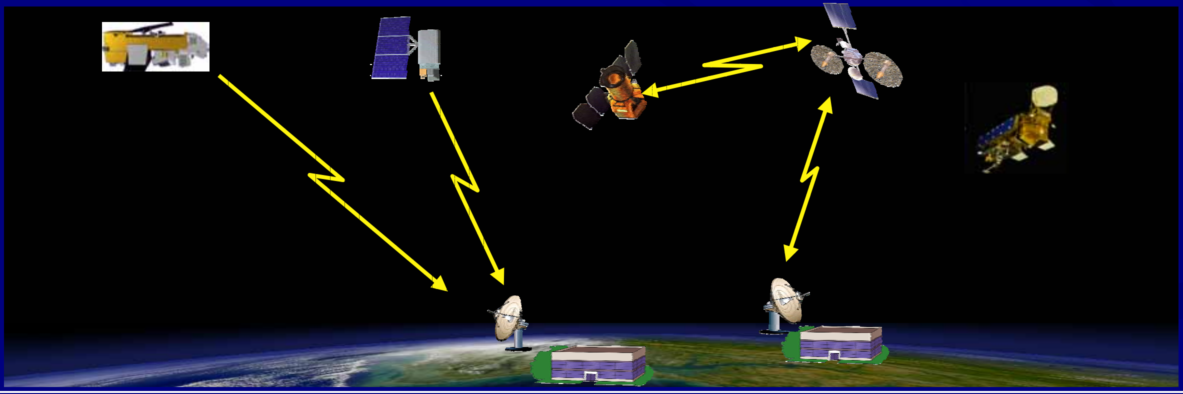
The Information Systems Division

Science Instruments & Missions - *Today*

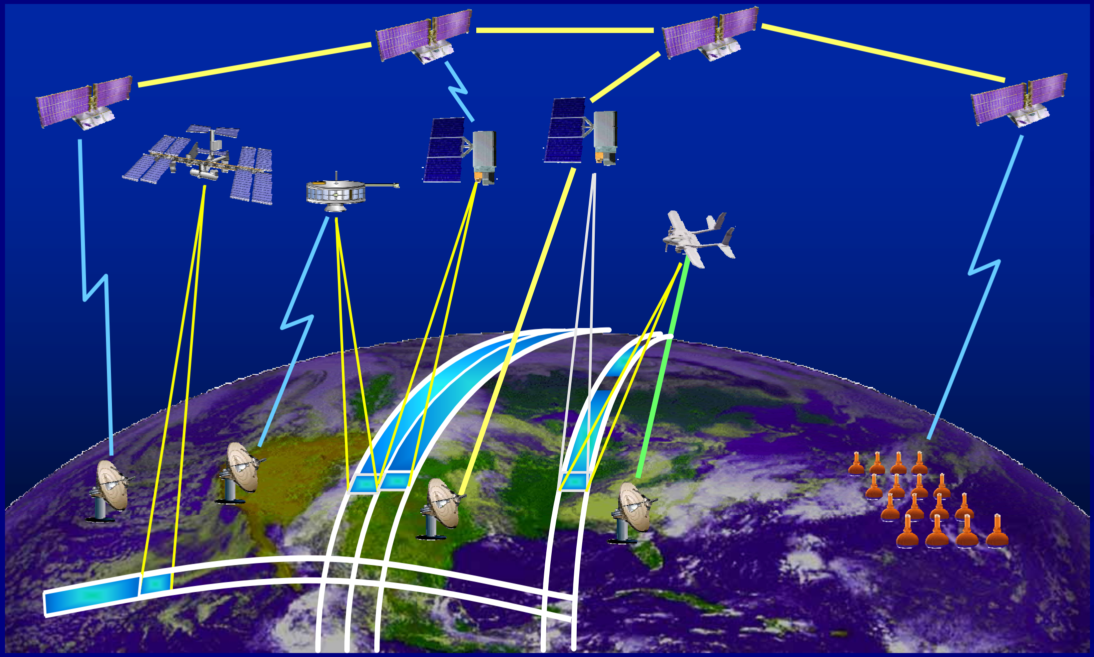
- *"Stovepiped" measurements and mission ops concepts by single, independent science instruments and platforms*
- *No real time information sharing between instruments & platforms*
- *Interspacecraft communications - a "bent pipe" for command uplinks & science data downlinks*
- *With few exceptions, lacking in dynamic, reactive, and selectable, sensor measurement modes*
- *Lack of (near) real-time, interoperable planning & scheduling systems to facilitate opportunistic science and discovery*



Sensor Webs - *Tomorrow*

"The best way to be ready for the future is to invent it."
John Sculley – CEO, Apple Computer

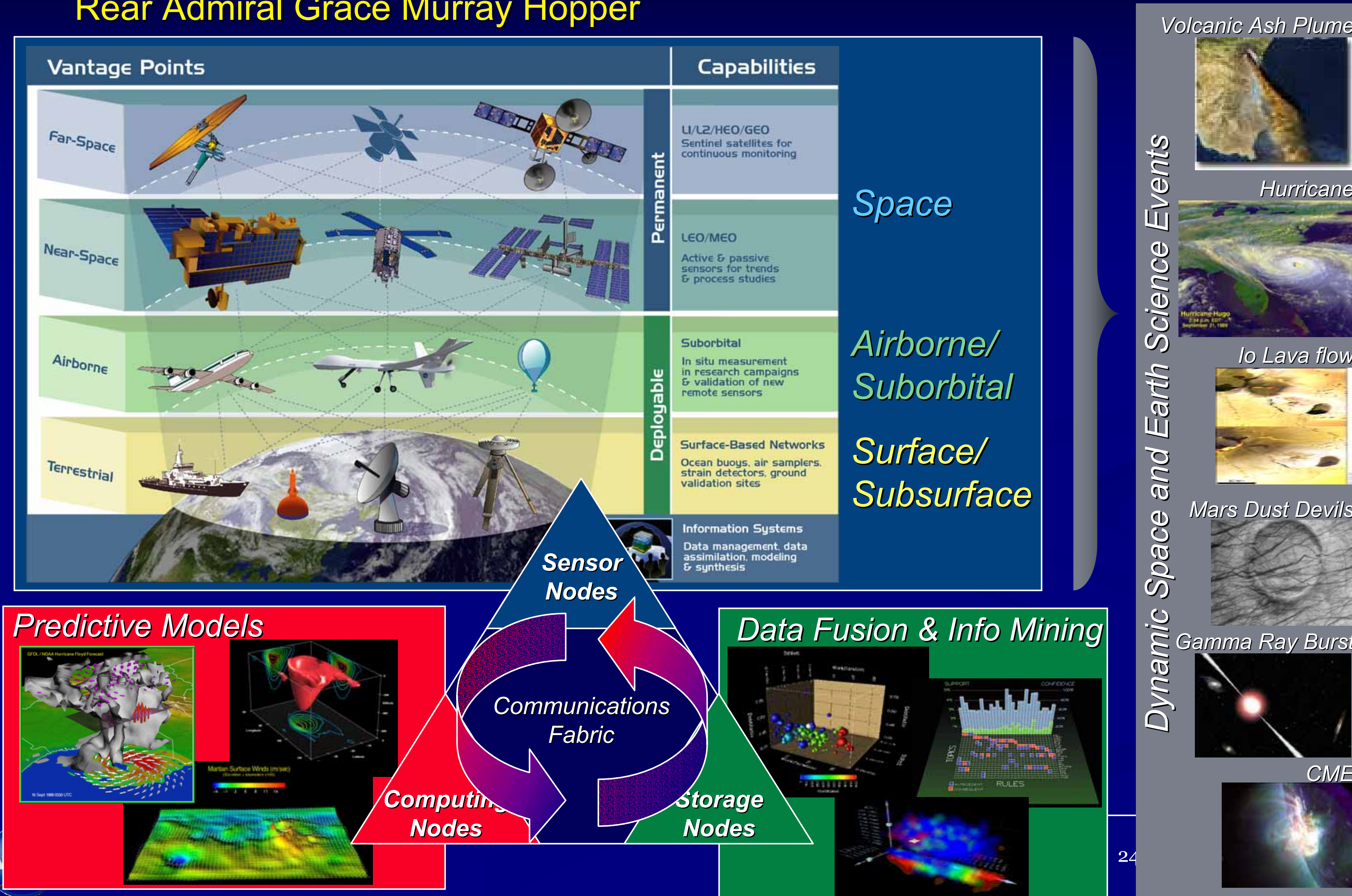
A sensor web is a coherent set of distributed "nodes", interconnected by a communications fabric, that collectively behave as a single, dynamically adaptive, observing system.



Sensor Webs: Adaptive Measurement Systems

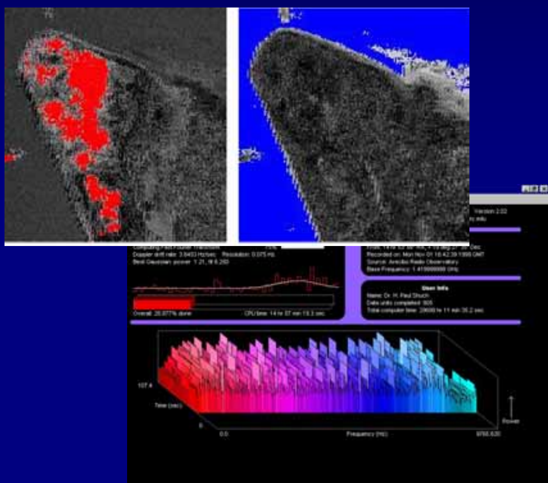
"Life was simple before World War II. After that, we had systems."

Rear Admiral Grace Murray Hopper



Sensor Webs: Dynamic Node Interactions

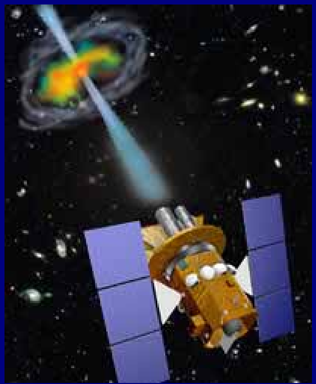
"Nothing endures but change. There is nothing permanent except change. All is flux, nothing stays still." Heraclitus



Autonomous Node Interactions	
Action	**By…**
Perform multi-sensor data fusion	*Synthesizing complementary sensor measurements*
Identify signals and extract features, patterns, …	*Performing signal processing and signature detection, sensor correlation, image processing, …*
Modify science goals, re-plan observations, schedule new, targeted measurements	*Establishing new goal priorities, exchanging sensor availability and operating state messages; identifying available sensor measurement services; …*

then…

Reconfigure Nodes & Perform New Measurements	
Reconfiguration	**Examples**
Temporal	*Change sensor measurement frequency*
Spatial	*Deploy sensor to new location; change resolution, FOV, viewing geometry, …*
Spectral	*Select only phenomenon-unique sensor bands*
Assimilation & Models	*Generate new initial conditions; invoke Mesoscale model; change model grid size, shape; …*
Organizational	*Reform sensor clusters; form new node relationships, modify command and control hierarchy, …*
Hardware & software	*Reconfigure programmable electronics; load and execute event specific algorithms, …*



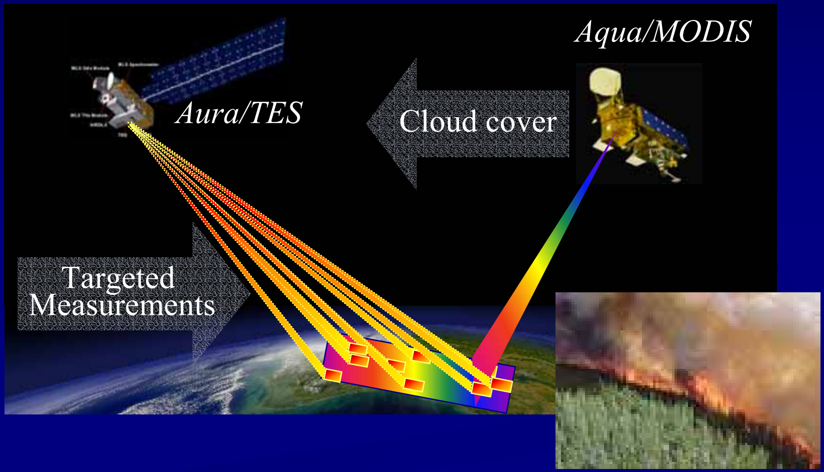
Sensor Web Observing Systems Representative *Science and Applications Benefits*

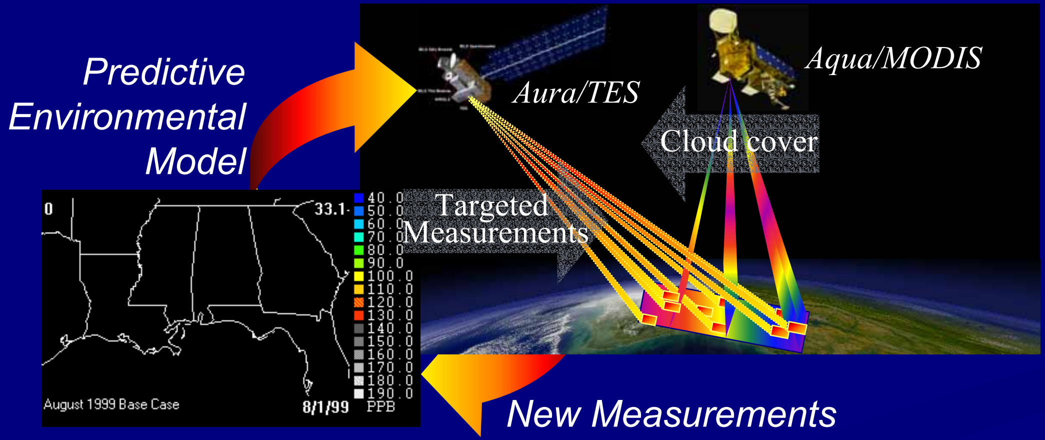
- *Intelligent data collection*

  …maximize useful science return by improved utilization of instruments and platforms

- *Event-driven observations*

  …improve reaction time to observe rapidly evolving, transient, or variable events and phenomena





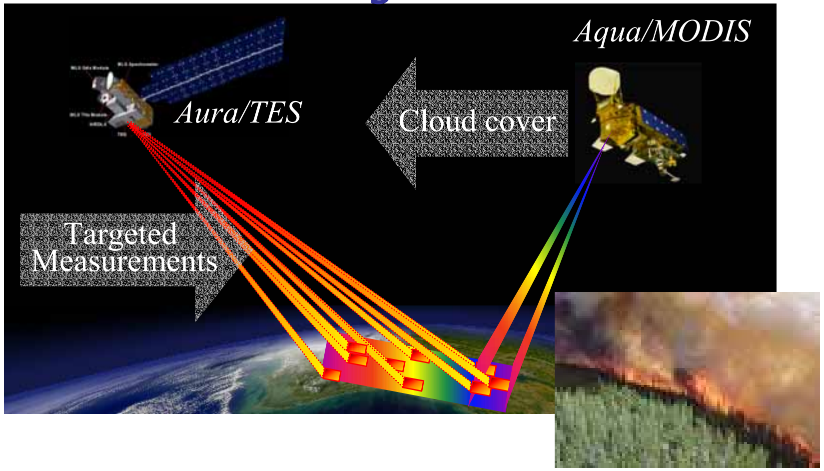
- *Model-driven observations*

  … improve predictive skill and reduce forecast model error growth by using model outputs to initiate new, *targeted* sensor measurements

Background
FY04 Sensor Web IRAD

- Problem: (April 2003; Sensor Web Microworkshop, Mark Schoeberl)
  - It is undesirable for Aura's TES instrument, a pointable IR interferometer, to make measurements in cloud contaminated fields of view.
- Solution:
  - Use Aqua/MODIS data to generate cloud mask and identify cloud-free targets within TES FOV *in real time*.
  - Prototype system to demonstrate how dynamic measurement techniques can maximize useful science return.

Event-driven targeted observations

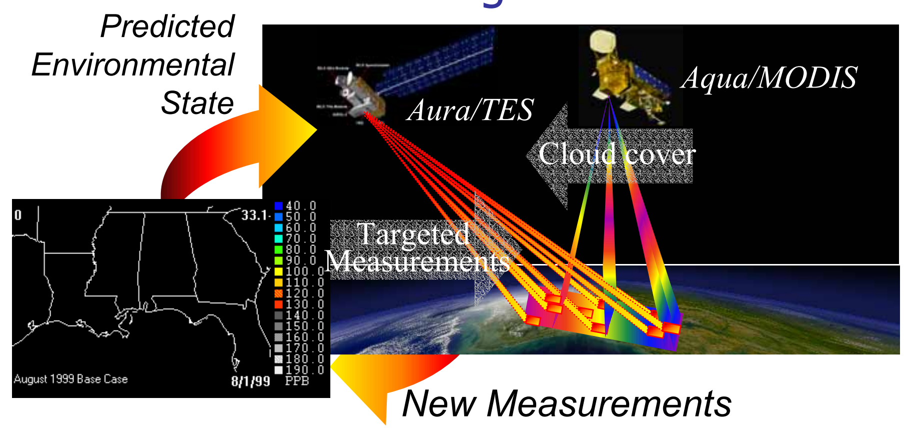


- Benefit:
  - Improved utilization of sensors, science instruments and platforms for real-time targeting applications.

Problem, Solution, Benefit
FY05 Sensor Web IRAD

- Problem:
  - It is desirable for Aura's TES to make targeted measurements where Tropospheric O_3 or other pollutants & precursors or are predicted to be significant.
- Solution:
  - Implement atmospheric chemistry model to predict occurrence of O_3 or other pollutants and demonstrate model-driven targeting.

Model-driven targeted observations



- Benefit:
  - Closed-loop feedback of new measurements into model can reduce forecast error growth and improve model predictive skill.

Approach

- Two principal objectives
  - Use atmospheric chemistry model output to drive targeted TES measurements
  - Identify and understand current Aura/TES operations; identify changes to accommodate Sensor Web ops concepts for future similar missions
- Characterize
  - Desired atmospheric chemistry model properties
  - TES measurement properties and mission observation modes

Approach - continued

- Identify available models for possible use and/or implementation
  - The Variable Grid Urban Airshed Model System (UAM-V®)
  - Models-3 Community Multiscale Air Quality (CMAQ) Modeling System (EPA, NOAA)
  - Global Ozone Chemistry Aerosol Radiation and Transport (GOCART) Model (Georgia Tech/Goddard)
  - Goddard Earth Observing System (GEOS) Chemistry Model (GEOS-CHEM)(Harvard University)

Approach - continued

- Characterize available models relative to:
  - Global vs. regional scale and available grid size(s)
  - Maturity and use by scientific community (NASA, NOAA, EPA, …)
  - Run-time environment requirements & performance metrics
  - Initialization and external data inputs
  - Content & format of gridded output variables
  - Need for ancillary meteorological and/or emissions models

- Develop scenario and ops concept for using model output to drive dynamic, targeted TES measurements
  - TES *step-and-stare* vs. TES *transect* measurement modes
  - Where to make measurements within predicted regions of interest? (e.g., high O_3, CO, NOX concentrations)

Approach - continued

- Develop
  - System design (hardware, software)
  - Characterize interfaces to key external data sources and systems

- Develop I&T plan
  - Stand-alone model implementation and validation
  - Spiral system development, integration, and test

Approach - continued

- Determine current Aura/TES mission/instrument planning and scheduling, and commanding processes
- Formulate alternative architecture that incorporates event-driven and model-driven Sensor Web ops concepts into:
  - Future Aura/TES operations
  - Goddard mission & science instrument formulation processes
- Identify impact upon future ground-, space-, and communications segment infrastructure

Results, Status, Next Steps

- Status
  - Project kick-off Dec 7, 2004.
  - Characterizing candidate models and TES measurements
- Next steps
  - Select atmospheric chemistry model
  - Develop science scenario(s) for pollution "events"
  - Develop ops concept(s) for model-driven TES targeting
  - Mid-term review - Spring 2005
- Demonstrate/present findings - September 2005